India's Water Futures: Drivers of Change, Scenarios and Issues

Overview of the Research in Phase I of the IWMI-CPWF Project on 'Strategic Analyses of India's River Linking Project'

[1]Upali A. Amarasinghe, [2]Tushaar Shah and [3]R P.S. Malik
[1]International Water Management Institute, New Delhi, India
[2]International Water Management Institute, Anand, India
[3]Agricultural Economics Research Centre, University of Delhi, New Delhi, India

Introduction

India is a vast country and its water availability varies significantly across regions and river basins. Water is in plenty in the north-eastern region, but few people live there and food production is low. In the north-western region most of the water resources are diverted for crop production, to such an extent that this region supplies food to the food deficit regions of the country, making it the largest provider of virtual water, that is, the water embedded in food. Water is scarce in the southern and western parts of the country, as the naturally drier areas come under increasing demand. Recurrent floods in the east and droughts in the south and west compound water related challenges that India is facing today. All indications are that India is heading towards a turbulent water future (World Bank 2005).

Proposed as an effective solution to the turbulent water future, the National River Linking Project (NRLP) envisages meeting India's future water needs up to 2050. The NRLP plans transferring surplus waters of the Ganga, Brahmaputra, Meghna, Mahanadi and Godavari river basins to the water scarce basins in the southern and the western parts. But, the proposed project is a major contentious issue in public discourses in India and outside India. On the one hand, opponents argue that the concept of NRLP itself is dubious and the water need assessment of the project is not adequate. The environmentalist view is that the assessment of water surpluses in river basins has ignored many ecosystem water needs. Activists say NRLP will displace millions of poor, mainly tribal population. And, others argue that the alternative water management options are less costly, easily implementable and environmentally acceptable. On the other hand, the proponents vision NRLP as the best option for facing India's turbulent water futures. They argue that NRLP will increase the potentially utilizable water resources and address the regional imbalances of water availability due to spatial variation of rainfall. However, many of the arguments, for and against the NRLP project so far, are based on assertions and opinions, and lack analytical rigor.

The International Water Management Institute and the Challenge Program for Water under the Consultative Group on International Agricultural Research (CGIAR) have started a three year research project for assessing India's Water Futures to 2025/2050 and analyzing what alternative options, including the River Linking Project, are adequate for meeting the future water challenges (CPWF 2005). The research project to some extent also attempts to fill the void of analytical rigor in the discourse on the NRLP to date. The specific objectives of the project are to:

- assess the most plausible scenarios and issues of water futures given the present trends of key drivers of water demand;
- analyze whether the NRLP as a concept can be an adequate, cost effective and a sustainable response in terms of the present socioeconomic, environmental and political trends, and if India decides to implement it, how best the negative social impacts can be mitigated; and
- contribute to a plan of institutional and policy interventions as a fallback strategy for NRLP and identify best strategies to implement them.

Phase I of the project focused on analyzing India's water future scenarios unto 2025/2050 and issues related therewith. This sets the stage for analyzing options for meeting water futures. Phase II, analyses how effective a response NRLP is for meeting India's water futures and its social costs and benefits. Phase III contributes to an alternative water sector perspective plan for India as a fallback strategy for NRLP. IWMI and CPWF would like to disseminate these findings of the research amongst the policy makers and the general public. The findings shall also add value to the on going debate on the NRLP, which is important to India and also to the neighboring countries of the region. This book is the first of a series of publications that brings out the results of the studies conducted under various themes of the project and also presented in various national workshops.

This volume, based on the studies conducted in the analysis in Phase I, has two parts. Part I, re-examining the key assumptions justifying the NRLP, provides an overview of the business as usual scenario and possible deviations of key drivers; gives a fresh look of the water supply and demand scenarios; and discusses some short to medium term policy options for meeting water needs of the immediate future. Part II presents the background studies conducted for the India's water futures analysis. These studies have assessed the recent trends, both spatial and temporal, of the key drivers of India's water futures. While some studies have projected the growth or estimated the requirements of key drivers in the future, others have assessed possible growth patterns and the constraints and opportunities of future growth.

India's Water Futures: Key Drivers of Water Supply and Demand

India is indeed a large country in many aspects that water has an intimate relationship. With more than one billion people, it has the world's second largest population now, behind China, and will have the world's largest population by the middle of this century. With more than a quarter of the population active in agriculture economic activities, it also has the world's second largest population whose livelihoods directly depend on agriculture. With agriculture supporting livelihoods of a large population, India also has the world's largest cropped area. With large crop areas under arid to semi-arid climatic conditions, it also has the world's largest irrigated area. With food gains as the staple food, India is the world's largest consumer and producer of cereals and pulses, and most of that, produced under irrigated conditions. With milk as the major animal product in the diet, Indian agriculture raises the world's largest cattle and buffalo population. And above all, it has the world's largest poor population and the majority of them live in rural areas and depend for their food security and livelihood on subsistence agriculture. And, India is also one of the large economies in the world with an impressive economic growth in recent years. Indeed, water has an important relationship to many of the above. And, water has shown to play an increasingly integral role in the rural livelihoods and economic growth.

Many drivers, either exogenous or endogenous to water system influence India's water futures (IWMI 2005). The exogenous drivers are mainly the primary drivers that set the direction of water futures. Some of the key drivers that are exogenous to water system of India are:

- changing demographic patterns;
- nutritional security and rural livelihood security;
- changing life style and consumption patterns;
- national food self-sufficiency;
- economic growth of India and that of other major regional economic powers;
- globalization and increasing world food trade;
- participation of private sector and nongovernmental organizations;
- political stability and relations between states and neighboring countries;
- technological advances, especially in water saving techniques; and
- global climate change.

The endogenous drivers to water system of a country are secondary drivers. They often are responses to the directions set by the primary drivers. Some of the key secondary drivers of the water futures of India are:

- changing agriculture demography;
- increasing water productivity;
- expanding groundwater irrigation and overexploitation;
- improving rain-fed agriculture;
- artificial groundwater recharge;
- rainwater harvesting;
- environmental water needs;
- recycling of urban waste water and marginal or poor quality water use;
- advancements in biotechnology; and
- desalinization etc.

Various assumptions on the direction and magnitude of these key drivers give rise to different scenarios of water futures. For example, nutritional security of all the people, livelihood security of rural population and food self-sufficiency of India were primary drivers of future water demand projections of the National Commission of Integrated Water Resources and Development (NCIWRD) (GOI 1999). Two population growth scenarios have given rise to the NCIWRD's low- and high-water demand projections (Verma et al. in this volume). The NCIWRD scenarios are considered to be the blueprint for future water development of India. And, the NRLP was virtually triggered by the projections of the NCIWRD high-water demand scenario. These scenarios were developed using the information on primary and secondary drivers available at the time of their projections. But the settings that surround these assumptions constantly change. A slight change of the assumptions of key primary drivers could significantly change the direction and magnitude of secondary drivers, and accordingly, the outcome, that is India's water futures (Paper 2 by Verma and Paper 3 by Amarasinghe et al. in this volume and Amarasinghe et al. 2007).

To what extent can the magnitude of these key drivers change in the future? The magnitude of the changes depends on vital turning points of primary drivers and the responses to them thereafter. Many turning points, which are usually difficult to predict, are mainly based on unforeseen human actions, political compulsions or natural catastrophes. Although turning points are difficult to predict, past trends of secondary drivers, which are largely the human responses to turning points, offer the best guide for us to extrapolate the likely course of trends to assess scenarios of water futures and explore policy options for meeting them. The assumptions of the primary and secondary drivers of the NCIWRD were mainly based on the priorities and trends in the 1980s. Before 1990s, livelihoods of a significant part India's rural population largely depended on agriculture. And, agriculture was the main engine of economic growth. With a large rural population and low foreign exchange reserves for large food imports, rural livelihood security and national food self-sufficiency were high priority then. However, the economic liberalization, which started in early 1990, has changed the course of many drivers. The various studies in this volume assess the turning points and recent trends of key drivers and their implications on India's food and water future scenarios.

Water Supply Drivers

Total Renewable Water Resources

The total renewable water resource (TRWR) of a country is the amount of resources that are available for utilization within its borders. The TRWR consists of water resources generated by endogenous precipitation within the borders—the internally renewable water resources (IRWR), and the net inflow from other countries through natural processes or allocated by treaties—the externally renewable water resources (ERWR). With 1,896 billion cubic meters (BCM) of surface runoff—636 and 1,260 BCM of ERWR[1] and IRWR—India has the seventh

[1] ERWR is the net inflow to India. Inflows to India are from Nepal and Burma and outflows from India are to Pakistan and Bangladesh.

largest, and about 4 % of the total renewable water resources (TRWR) of the world (CWC 2004). However, due to un-even rainfall, TRWR vary significantly across river basins (Table 1). Basins in the north and east, Ganga, Brahmaputra and Meghna, Mahanadi and Godawari, have most of India's IRWR (Table 1).

Climate change, an exogenous driver to the water system, increases the spatial and temporal variation of TRWR. Recent studies show that with climate change, Mahanadi, Brahmani, Ganga and Godavari will experience higher precipitation and larger surface runoff, while many peninsular basins will experience lower rainfall and lower surface runoff (Gosain et al. 2006[2]). Although, the aggregate of TRWR at the national level show no major changes, regional disparities are likely to increase further. Moreover, with increasing incidence of high-intensity short-duration rainfall events due to climate change, the temporal variation of surface runoff will also increase (Mall et al. 2006).

Table 1. Water resources of India.

River basins	Total water resources (TRWR)	Utilizable surface water resources	Total ground-water resources	Potentially utilizable water resources (PUWR)	PUWR - % of TRWR
	km3	km3	km3	km3	%
Indus (Up to border)	73.3	46.0	27	72.5	99
Ganga	525.0	250.0	172	422	80
Brahmaputra and Meghna	585.6	24.0	36	60	10
Subernarekha	12.4	6.8	2	9	70
Brahmani-Baitarani	28.5	18.3	4	21	74
Mahanadi	66.9	50.0	17	66	99
Godavari	110.5	76.3	41	117	106
Krishna	78.1	58.0	26	84	108
Pennar	6.3	6.9	5	12	187
Cauvery	21.4	19.0	12	31	147
Tapi	14.9	14.5	8	23	153
Narmada	45.6	34.5	11	45	99
Mahi	11.0	3.1	4	7	64
Sabarmati	3.8	1.9	3	5	135
WFR1[1]	15.1	15.0	11	26	173
WFR2[2]	200.9	36.2	18	54	27
EFR1[3]	22.5	13.1	19	32	142
EFR2[4]	16.5	16.7	18	35	212

Source: GOI 1999, CWC 2004

Notes: 1- WF1 includes west flowing rivers of Kutch, Saurashtra including Luni; 2 – WF2 includes west flowing rivers between Tapi and Kanayakumari; 3. EF1 includes east flowing rivers between Mahanadi and Pennar; 4. – EF2 includes east flowing rivers between Pennar and Kanayakumari; 5 – Minor river basins drainage into Bangladesh and Myanmar

[2] Brahmaputra and Indus were not included in this study.

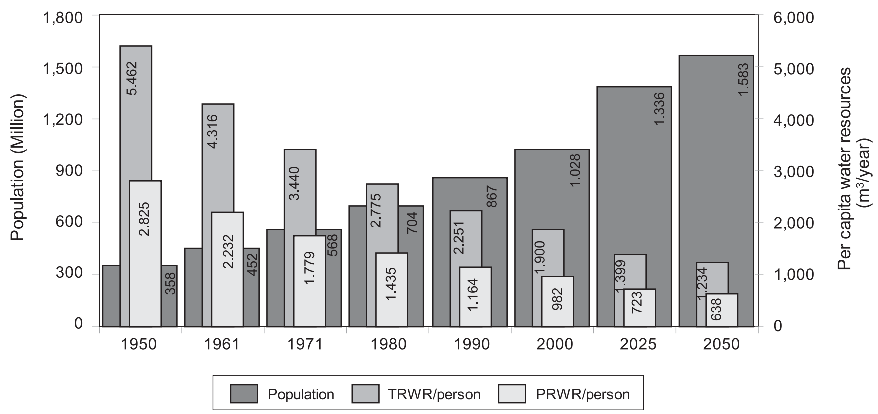
With monsoonal weather patterns, most of the rain that contributes to TRWR in many river basins falls in less than 100 days in the summer months between June and September and a major part of precipitation falls in locations where surface runoff cannot be captured due to limited storage potential. Therefore only a part of the TRWR can be stored or diverted for human use within a basin.

Potentially Utilizable Water Resources (PUWR)

The PUWR is the portion of the TRWR that can be captured for human use within a river basin. This depends on the variation of precipitation and the potential of storage and diversion facilities. For India, this is estimated to be only 58 % of the TRWR. Among the river basins, Brahmaputra and Meghna have the largest TRWR, but with limited storage opportunities, only 10 % of TRWR can be captured as PUWR (Table 1).

The population growth, an exogenous driver to the water system, exacerbates the limitations of PUWR in some locations. The PUWR per person in India in the middle of this century is projected to be 701 m^3, which is only 22 % of the PUWR per person in the middle of last century, indicating more than four-fold increase of population over this period (Figure 1). Few basins, which are already water stressed now (Amarasinghe et al. 2007), will have very low per capita PUWR by 2050. Such conditions—below 500 m^3 of per capita PUWR—are, as Falkenmark et al. 1989 described are extremely unhelpful even for human existence.

Figure 1. Growth of population and declining per capita water supply in India.



Climate change, an exogenous driver to the water system could also reduce PUWR. With increasing incidence of high intensity and short duration rainfall events, the incidence of flash floods increases. Thus, the capacity to capture or divert water will diminish and as a result PUWR will reduce. The PUWR will also be reduced in basins that are predicted to have low rainfall and runoff. Although the magnitude of the reduction in PUWR is still not exactly clear, the PUWR of many Indian river basins could reduce with climate change.

However, various responses are available for augmenting PUWR in water stress regions. Rainwater harvesting (RWH), artificial groundwater recharge (AGWR) and intra-basin or interbasin water transfers (IBWT) are three popular methods practised for augmenting PUWR. The RWH and AGWR are mainly local level interventions and they will generate immediate impacts in a neighborhood of the location where water is captured. On the other hand, the IBWT, which generally requires large infrastructure development, including storage reservoirs, barrages, river links, and distributary canals etc., can increase water availability in far away locations from where water is originally stored or diverted. However, these interventions could incur social cost too. Extensive RW and AGWR in the up-stream of river basins, especially in those which are approaching closure, can impact the uses and users in the down-stream of a basin. The IBWTs can displace many people and submerge large areas of forest or productive land. Yet, all these interventions can have significant spatially distributional benefits. The main question here however is, that with a significant part of the precipitation occurring in short spells, how much can these interventions effectively augment PUWR in Indian river basins?

Rainwater Harvesting

The extent that RWH can augment the PUWR depends on the capacity of RWH structures to store part of the unutilizable water resources. The exact estimates of this are sketchy. The study by Bharat et al. (Paper 10 in this volume) using a district level analysis shows that 99 km^3 of surface runoff are available for rainwater harvesting in 25 million ha of rain-fed lands. These lands exclude the extreme arid and extreme wet rain-fed areas. However, whether all of this quantity of harvested water will augment the net PUWR is not clear. Some harvested water could well have been captured by reservoirs in the downstream, and may already have been included in the present estimate of PUWR. In spite of whether it net augments or not, the RWH is very useful for distributing significant positive benefits to vast areas that a few storage structures cannot provide. Bharat et al. study also shows that it requires only about 20 km^3 of the above runoff to be captured to bring relief to about 25 million ha of rain-fed lands suffering from mid-seasonal droughts. If this portion can be part of the unutilizable water resources, then it is only 2.5 % of the unutilizable runoff and augments the present estimates of PUWR only by 1.7 %.

There are other viewpoints of RWH too. Kumar et al. 2006 argue that the impacts of many local watershed level RWH interventions will not always aggregate at the basin level. This argument is based on the premise that much of the water that RWH captures is part of the water already captured and used in the downstream. According to Kumar et al. the potential of RWH for net augmenting of PUWR in water scarce areas is low due to varying hydrological regimes, extremely variable rainfall events, and constraints of geology. Furthermore, the demand for water is low in locations where rainwater can sufficiently be captured, thus generating only a small economic benefit vis-à-vis to the cost of construction of many RWH structures.

Artificial Groundwater Recharge (AGWR)

The total renewable groundwater resource of India is estimated to be 432 BCM. For the country as a whole, only about 37 % of the renewable groundwater resource is withdrawn at present. But, with intensive withdrawals for irrigation, groundwater resources of some regions are severely over-stressed. The number of overexploited bocks is increasing, where groundwater abstraction well exceeds the replenishable recharge (CGWB 2008). Yet, the uses and users in the domestic, irrigation and industrial sectors that depend on groundwater are increasing. Sustaining the groundwater supply for various services, especially in the severely water stressed blocks and in areas approaching overexploitation, and maintaining the base flow in rivers in the dry season is indeed a major challenge.

AGWR have the capacity to alleviate the stress in groundwater overexploited areas. An ideal example is the mass movement of groundwater recharge in the Saurashtra region of western India (Shah 2000). According to the master plan prepared by the Central Groundwater Board, 36 BCM of unutilizable surface runoff can be captured through AGWR (CGWB 2008). This augments India's PUWR by 3.4 %. However, given the magnitude of the unutilizable surface runoff, many considered this estimate to be quite low. In fact, Shah 2008 argues that groundwater recharge using the existing dug-wells alone can exceed the potential of AGWR estimated in the master plan. Regardless of the magnitude of the recharge, AGWR is an important tool for net augmenting the PUWR and distributing the hydrological and economic benefits, as in RWH, to vast areas.

Intra-basin or Interbasin Water Transfers (IBWT)

The IBWTs perhaps have the potential for large net augmentation of PUWR. They can capture unutilizable runoff of water surplus basins through large reservoirs or barrages, and then transfer them to water scarce areas within the same or to other basins. For example, the NRLP envisages transferring 178 BCM from water surplus Brahmaputra, Maghanadi and Godavari basins to water scarce basins such as Krishna, Cauvery, Pennar, and Sabramati, in the southern and western regions (NWDA 2006). If all that diverted water in the NRLP is from unutilizable surface runoff, then it augments PUWR of India by 18 %. Indeed, this is one of the major contentious issues in recent discourses. How, such large quantum of surplus water, mainly floods, in some basins can be transferred to other basins when they also experience floods is indeed an important question.

In spite of the above concern, the IBWTs can have many socioeconomic and hydrological benefits. For example, the NRLP expects to mitigate the damage caused by floods which ravages the eastern parts of the country every year, temporarily displacing many people, destroying crops and livestock, and disrupting the livelihood of many, especially the rural poor. The NRLP also provides an insurance against recurrent droughts and expects to recharge groundwater of overexploited blocks in many parts of the southern and western parts of India. In fact, it can alleviate water scarcities in many river basins, which in some regions are becoming a serious constraint on further economic growth.

However, many other drivers, which are exogenous to the countries water system, also affect implementing IBWTs (Shah et al. 2006). Financing such mega projects, estimated to be more than US$125 billion (in 2000 prices) for NRLP, and their impacts on other social-welfare activities are serious concerns under the prevailing economic conditions at present. But, with rapid economic growth, increasing at 7-9 % annually in recent years, financing of large IBWTs shall not be a major constraint on a trillion dollar[3] economy in few years time.

The IBWTs often displace lakhs, if not millions of people and submerge large areas of forest and productive agriculture land. And the hardest hit by such displacements are the weakest sections of society, including tribal communities with forest as the main livelihood resource, and landless laborers who depend for their livelihood on the daily wages from working in those agriculture lands that get submerged. The resettlement and rehabilitation issues, if not properly addressed, are major bottlenecks for implementing large IBWTs.

[3] India's GDP has already passed one trillion. It was US$1,027 billion in 2007.

Political stability and relations between states and neighboring countries are also major drivers of planning and implementing IBWTs. Often, IBWTs cut across several states and at times, several countries. In NRLP, it is even required to build storage reservoirs in other countries. Therefore, the existing level and the future prospects of trans-boundary or inter-state cooperation are major determining factors determining the feasibility of such IBWTs.

Ecosystem water needs, another major driver, is often ignored in IBWT planning. But they are highly contentious issues in the discourses thereafter. An important question often raised in these dialogues are whether water resources required for sustaining a healthy ecosystem in one basin can be considered for augmenting water resources in other basins. According to Bandyopadhyaya and Praveen 2003, there is no free surplus of water available to be transferred from one river basin to another basin. All water in the unutilizable water resources, including floods, performs an important ecosystem service. Such assumptions, indeed, are an extreme view point in-terms of ecosystem water needs. A compromised formula can determine the extent of surplus that can be transferred from the water surplus river basins. How much of water can be transferred depends on whether the environment is considered as a primary driver of water supply or as another sector of water use.

If environment is considered as another sector of water use, it often loses. With increasing demand, different sectors compete for scarce water resources. The agriculture, domestic, industrial, navigation and hydropower sectors have stakeholders who have a voice and also theoretically can afford to pay for the services. However, the environmental sector has no voice by itself or cannot pay for its water demand. Thus, as a 'water use sector', the water needs of the ecosystems are often ignored in IBWT planning. For instance, the NCIWRD water demand scenarios considered the environment as a water use sector, and allocated only 10 BCM, or less than 1 % of TRWR.

However, this situation can change if eco-system water needs are considered as a primary driver of water availability. The premise here is that parts of the floods in the rainy season and a minimum river flow in the dry season play a major role in servicing the needs of the riverine ecosystems. Thus, a major part of the unutilizable water resources cannot be captured and transferred for water use in other basins. In this context, it is important then to know the magnitude of the water needs for sustaining ecosystem services in river basins.

Environmental Water Demand

As a primary driver, a good starting point is to assume that at least a minimum environmental flow (EF)[4] requirement is to be maintained for providing ecosystem services of a river basin. Two factors determine EF. They are the natural hydrological variability of the river flow, an endogenous driver to the water system, and the environmental management class that the river ought to be maintained, often an exogenous driver to the water system. The latter depends on human decisions on the qualitative importance they want to place on riverine ecosystems. Smakhtin et al. (Papers 20 and 21) defined six environmental management classes (EMC), and

[4] This is part of the research conducted under the project for assessing environmental water demand of river basins of India. Details of the procedures and estimation are available in Smakhtin and Anputhas 2007 (or paper 14 in this volume) and Smakhtin et al. 2007 (paper 15 in this volume).

determined the minimum flow if a river ought to be maintained under different EMCs. The EMC class A corresponds to the pristine conditions of a river. Other—classes - B to F - correspond to slightly, moderately, largely, seriously and critically modified river conditions. The EMCs E to F describe the development states of a river basin where the basic ecosystem functions are destroyed to the extent that the changes to the river ecosystem are irreversible. Table 2 shows the EF under different EMCs for 12 river basins of India, which account for 78 % of TRWR of India. The total EF of 12 basins varies from 70 % of TRWR in class A to 13 % in class F.

Table 2. Minimum river flows of Indian river basins.

River basin	Natural MAR[a] (Bm^3)	Environmental flow (EF) – % of MAR					
		A	B	C	D	E	F
Brahmaputra	629.1	78	60	46	35	27	21
Cauvery	21.4	62	36	20	11	6	3
Ganga	525.0	68	44	29	20	15	12
Godavari	110.5	59	32	16	7	4	2
Krishna	78.1	63	36	18	8	4	2
Mahanadi	66.9	61	35	19	10	6	4
Mahi	11.0	42	17	7	2	1	0
Narmada	45.6	56	29	14	7	4	3
Pennar	6.3	53	28	14	7	4	2
Sabarmati	3.8	50	24	12	7	3	2
Subernarekha	12.4	55	30	15	7	3	2
Tapi	14.9	53	30	17	9	5	3
Total MRF demand (Bm^3)		1,065	731	501	353	260	202
Total - % TRWR		70	48	33	23	17	13

Source: Amarasinghe et al. 2007a

Note : [a] Mean annual river runoff

Ideally, one would like to maintain rivers in their pristine condition, or in EMC class A. The EF requirement for maintaining Indian rivers in EMC class A is even more than the estimate of the total unutilizable water resources at present. And, under such conditions, no water surpluses are available for transferring between basins, and it is feasible only in low populated and low developed river basins. Given the present level of population and economic growth, maintaining large EF as in EMC class A is impossible. In fact, none of the major rivers can be maintained in pristine conditions.

The total water requirement for maintaining rivers in EMC class B is 731 Bm^3. Although this level of demand is within the total unutilizable water resources of all river basins, a few rivers still require a substantial part of the utilizable water resources for meeting environmental water needs. The EMC class C maintains a river under moderately modified conditions. The minimum flow requirement under this scenario of all river basins, except Cauvery, Pennar and

Tapi, is less than the unutilizable water resources (Amarasinghe et al. 2007). The unutilizable water resources of Brahmaputra, Ganga, Mahanadi, and Godavari substantially exceed the corresponding EF under EMC class C. Thus part of the excess flows in these basins can theoretically be transferred to other basins. Nevertheless, if environmental water demand gets high priority, the effective water supply that is available for augmenting PUWR could further diminish in many river basins.

Besides these concerns, some studies show that the estimates of PUWR that are available at present are significantly over-estimated (Garg and Hassan 2007). This is mainly due to double counting of surface and groundwater resources in the dry season. According to Garg and Hassan, the presently available estimate of PUWR in India is overestimated by at least 66 %. Such estimates, indeed, are alarming and require thorough scrutiny before they are accepted in water supply and demand modeling and such a scrutiny also requires a clear understanding of the interaction of surface and groundwater flows in river basins, for which the available data on water resources in many river basins are inadequate. According to Mohile et al. (Paper 19 in this volume), a static estimate for PUWR is not any more a useful concept. Instead, they prefer to replace PUWR by 'limits of utilization' of water resources in a basin. The limits of utilization depend not only on the natural flows and the engineering and agronomic constraints, but also - on environmental constraints and methods of utilization of water resources. They propose that any surplus water over and above the 'limits of utilization' can be transferred to other basins. A major drawback of this approach is the way it estimates potential utilization in a river basin. It depends on a set of assumption of trends and magnitude of drivers of water demand and the potential water use according to them. As discussed before, these assumptions, especially on primary drivers, are difficult to forecast. Therefore, drivers pertaining to water demand estimation themselves require periodic assessment.

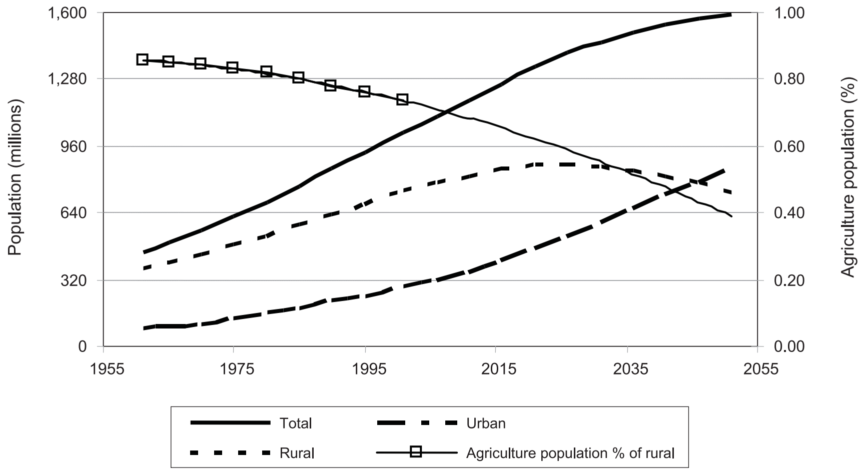
Water Demand Drivers

Changing Demographic Patterns

Population growth has a central place among primary drivers of future water demand. The changing regional demographic patterns also play an equally important role in assessing the composition of regional water demand. This is important for a large country like India with a significant spatial variation of water availability, and also when irrigation is the largest consumptive water use sector in many regions. Irrigation has played a vital role in the past in many states where a major part of the rural population depended on agriculture for their livelihoods.

But, the regional demographic patterns are changing with rapid urbanization. Study by Mahmood and Kundu (Paper 6 in this volume) projects India's total population to reach about 1.6 billion by 2050 and stabilize thereafter (Figure 2). It has been estimated that about 53 % of the population will live in urban areas by 2050. According to others, this is even a conservative estimate of urban population growth in India (Y.K. Alagh cited by Amarasinghe and Sharma 2008). In either scenario, demographic trends of many states will change significantly by the second quarter of this century. Many states will have more cities with major urban centers, and more urban than rural population.

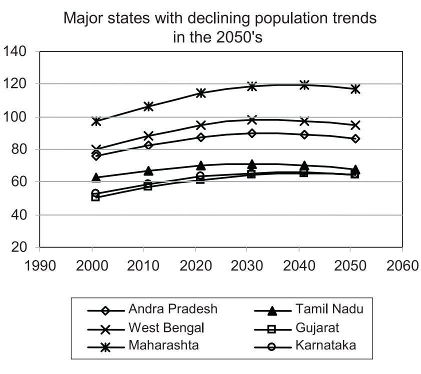
Figure 2. Urban, rural and agriculture depended population in India.

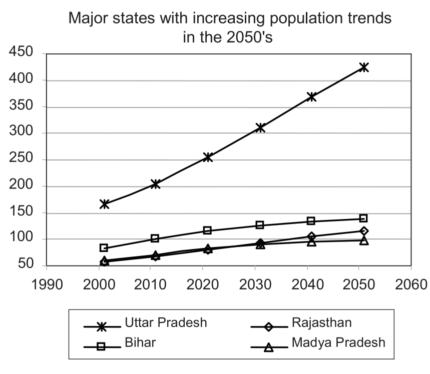


Source: FAO 2005, Mahmood and Kundu 2006

An examination of the demographic trends at the state level suggests that population of Andhra Pradesh, Kerala, Karnataka, Punjab and Tamil Nadu, will have a declining trend by 2050, and a significant part of the population of these states will live in urban areas (Figure 3). The states Haryana, Gujarat, Orissa, Maharashtra and the West Bengal will have moderately declining population. In all of the above states, water demand for the domestic and industrial sectors is likely to increase rapidly, and the water use patterns in the agriculture sector will change.

Figure 3. Population growth trends in major states.





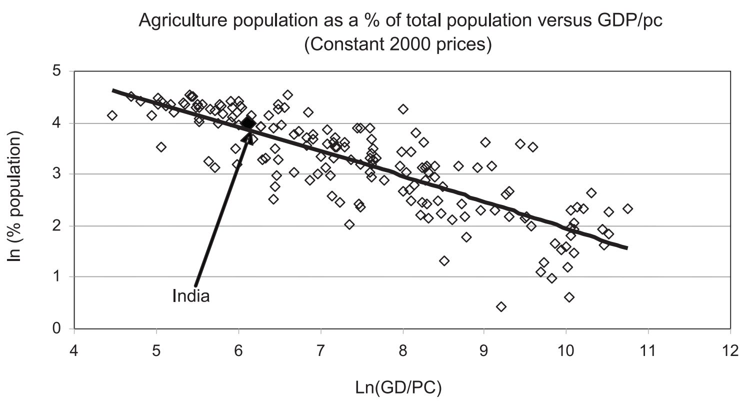
However, the so called 'BIMARU' states, Bihar (including Jharkhand), Madhya Pradesh (including Chhattisgarh), Rajasthan and Uttar Pradesh (including Uttaranchal) will only continue to have increasing population, but will continue to have a substantial rural population by 2050. The pressure for agriculture land and water will intensify in these states, where the natural resource base is already over stressed due to extensive agriculture activities.

Many national level projections often do not incorporate regional population growth patterns. This is one major shortcoming of the assumptions of the NCIWRD scenarios. They estimated the future population of states and basins on the basis of the 1991 population figures (page 70 in GOI 1999). Such an assumption can over estimate the rural population and part of the rural population that depend for their livelihood on agriculture in many southern and western states.

Rural Livelihood Security

Rural livelihood security, for which agriculture is the main source for many people, was a vital component of the overall rationale for agriculture water demand projections in the past. However, recent trends suggest that the agriculture demography is fast changing with increasing employment in the nonagricultural sectors. The study by Sharma and Bhaduri (Paper 7) suggests that India may be at the 'tipping point' of the transition in its agriculture dependent population to nonfarm activities. Agriculture will be a part-time employment activity for many habitants in rural areas. Over the last four decades, the agriculture-dependent population has declined from 86 to 74 %. This percentage is likely to decrease further, and could reach even below 40 % by 2050 (Figure 2). Such trends are compatible with the present level of agriculture population of countries with similar economic conditions that India shall experience by 2050 (Figure 4), and perhaps could accelerate in the future as the National Sample Survey show that significant number (40 %) of farmers say that would like to exit farming for better opportunities in the nonfarm sector.

Figure 4. Agriculture population across selected countries in the world.



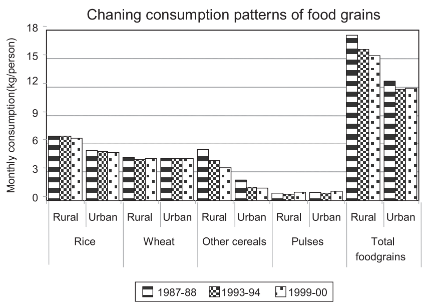
Source: WRI 2007 and FAO 2007

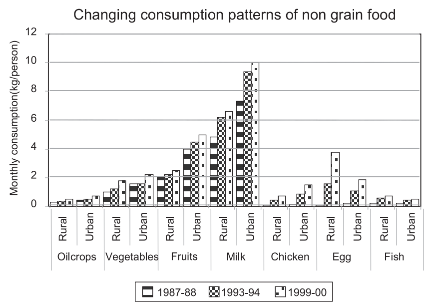
The implication of the changing agriculture demography is that, although the agriculture dependent population in India will increase in the near-term, the growth rate shall start to decline soon. And in 50 years from now, India will have even less population that depends on agriculture than it is now. Sharma and Bhaduri study further shows that withdrawal of rural youth from agriculture is not significantly related to access to irrigation. Rural livelihood security shall decline in importance as a primary driver in determining future irrigation water demand in India. This was another contentious assumption in the NCIWRD projections, where it was assumed that irrigated agriculture would be a major part of the future rural livelihood security.

Changing Consumption Patterns

Generally, the food consumption patterns of a country largely determine what its people produce in the agriculture fields. More than two-thirds of the food consumed in India at present is produced under irrigated conditions. And due to large marginal to small land holders, the producers are also the main consumers of the crops they produce. Thus, the local consumption patterns play a pivotal role in cropping pattern decisions in irrigated agriculture. In the past, grain crops dominated the agriculture production patterns, as food grains provided a major part of the daily nutritional intake. However, a subtle change in food consumption patterns has been surfacing in the recent past in both rural and urban India. While, the demand for food grains, especially for rice and coarse grains in both rural and urban areas are declining in the 1990s, the demand for non-grain food crops such as vegetables, fruits and oil crops, and animal products such as milk, chicken, eggs and fish is increasing (Figure 5).

Figure 5. Changing consumption patterns in rural and urban areas.





Source: NSSO surveys

Increasing income and urbanization will further increase the demand for non-grain food products in the Indian diet. The study by Amarasinghe et al. (Paper 8) in fact shows that non-grain crops (oil crops and vegetable oils, roots and tubers, fruits, vegetables and sugar), and animal products (mainly milk, chicken, eggs) are expected to provide a major part of the nutritional intake by 2050. Food grains provide more than two-thirds of the nutritional supply today, and this will reduce to less than half by 2050. As a result of decreasing per capita grain consumption in both the urban and rural areas, and the rate of urbanization, the total food grain demand will increase slowly. However, due to increasing consumption of animal products, the feed grain demand will increase several fold. The demand for non-grain crops will also increase substantially. Therefore, non-food grain crops will consist of a major part of the additional irrigation geography in the future.

This is quite in contrast to the assumptions of the NCIWRD scenarios, in which they projected a significantly high additional food grain demand. In fact, the NCIWRD projection of demand for food grains exceeds 22 kg/month/person by 2050, and that level of food grain consumption alone can provide a calorie supply of 4,000 kcal/person/day. Such level of calorie supply is highly unlikely as it is even higher than the calorie intake in the most developed countries with animal product dominated diet (Amarasinghe et al. Paper 3). Nevertheless, high demand for food grains along with national self-sufficiency assumption required NCIWRD scenarios to project a large irrigated area expansion.

National Self-sufficiency

Another primary driver that dominated the selection of cropping patterns of agriculture in general, and irrigation in particular was full national self-sufficiency of food grains. This assumption was mainly based on the three concerns that 1) India has a large population and the food grains are the staple food of its people with mainly a vegetarian diet, because of which large production deficits, such as in the 1960s, are not acceptable; 2) agriculture was the main driver of economic growth and has contributed to substantial part of the gross domestic product; and 3) India's foreign exchange reserves are too low to import large quantities of food from the world market. The first is still true, but as mentioned before, demographic and consumption patterns are fast changing, and demand for non-grain food and feed products are increasing. With changing consumption patterns, there will be more opportunities for Indian farmers to increase income from growing high-value non-grain food products. Moreover, India's agriculture export and import patterns are also changing. Although the share of total agriculture exports is decreasing, which is natural with rapidly growing industrial and service sectors, the total quantum of exports has been increasing in recent years (Paper 9 by R.P.S. Malik). Also, India has been importing a significant part of the requirements of vegetable oil, and also some pulses, fruits and nuts etc. However, the value of agriculture exports at present far exceeds that of imports, and the difference is widening gradually. And with expanding global trade, India will have more opportunities for increasing agriculture exports, and pay for its agriculture imports.

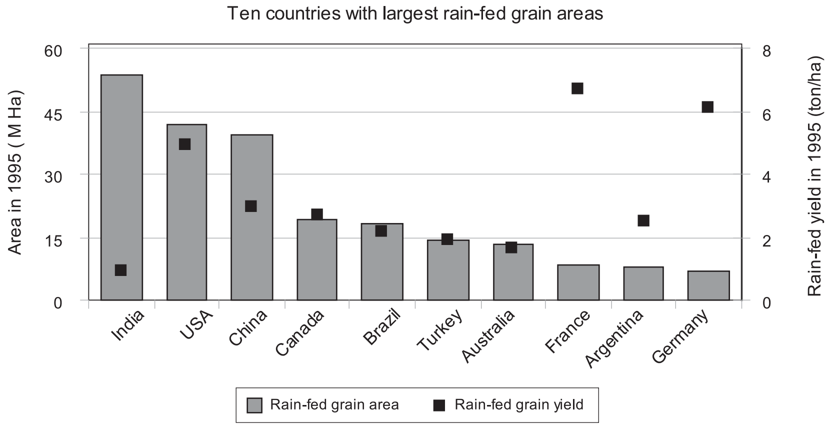
In the past, low foreign exchange reserves were indeed a constraint on large food imports. But that was only when the gross domestic product was only a few hundred billion dollars, and food grain production was a substantial part of it. But it is no longer valid under the prevailing economic growth. India has a trillion dollar economy now and has large foreign exchange reserves in comparison with those in the early 1990s. The share of the agriculture sector, let alone the value of food grain production, is only about 23 % of the total GDP in 2000 (WRI 2007). And this share will decrease further, and India will have sufficient foreign exchange reserves to pay for even large food imports in a few decades time.

However, the only concern that India should have in large quantity of food imports is its effect on prices. Potential price increases due to large food imports from countries such as India and China can hurt the very consumers that the imports would expect to help, and also can increase the volatility of global grain markets in the years of significant grain production deficits. So, a reasonable degree of food self-sufficiency, purely because of the volatility in the grain prices in the markets, can still be a good assumption for projecting future food and water demand.

Realizing the Potential in Rain-fed Agriculture

While India ranks the highest among the countries with rain-fed agriculture area, it ranks one of the lowest in rain-fed yield (Figure 6). The total food grain production from the existing land can be increased 30 % by raising the rain-fed yield by just one ton, which is still much lower than the rain-fed yields of many other large rain-fed food grain producers.

Figure 6. Rain-fed yield of major food grain producers in the world.



Source: IWMI 2000

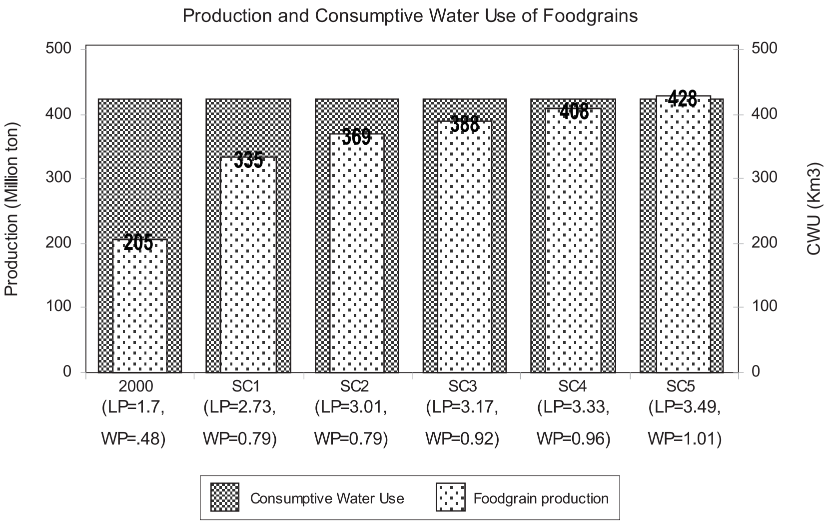
Sharma et al. (Paper 10) finds that frequent occurrence of mid-season and terminal droughts were the main cause for crop failures or low yield in a major part of the rain-fed cropped area. Small supplemental irrigation during the water stressed periods of mid-season and terminal droughts can significantly increase the rain-fed yields. Providing supplemental irrigation through decentralized, more equitable and targeted rainwater harvesting structures can help millions of resource poor farmers in rain-fed faming. They shall also reduce the requirement for large-scale irrigation projects, which in the present states of water scarcities require large inter or intra-basin water transfers. However, small RWH interventions could bring maximum benefits provided that the marginal cost does not exceed the marginal economic benefits in basins with high degree of development and that there are no significant disparities of water demand in the upper and lower catchments, where there is no significant tradeoff in maximizing benefits of the upstream vis-à-vis optimizing the basin wide benefits (Kumar et al. 2006).

Increasing Crop Productivity

Assumption of the growth in crop yields is a major driver in determining the requirement of additional agriculture area and irrigation. For example, India can be self- sufficient in food grains without any additional irrigation if it doubles the crop yield in 50 years (Figure 7)[5]. If India can attain such level of productivity in 50 years from now, it is only similar to the productivity levels of China today, although both countries had more or less similar productivity levels 50 years ago. Indeed, there does seem to be a significant scope for increasing crop productivity over the next few decades.

[5] In 2000, India was self-sufficient in food grains with a production of about 205 Mmt. The land and water productivity of food grains in 2000 was 1.67 ton/ha and 0.48 kg/m^3. With two-fold increase in land and water productivity, as shown in Scenario 4, India can increase food grain production over 400 Mt without any additional consumptive water use. This level of production is more than sufficient to meet the consumption demand of 377 Mmt projected by Amarasinghe et al.; Paper 6).

Figure 7. Food grain production under different land and water productivity scenarios.



Source: Authors estimate using PODIUMSIM

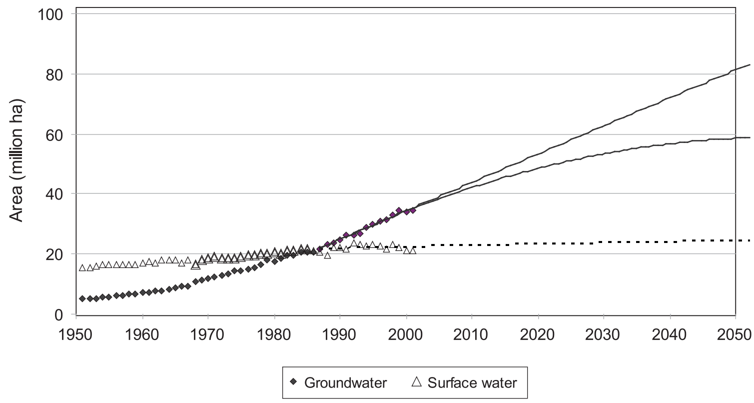
Kumar et al. (Paper 14) show that significant variations of productivity exist across farms in the same area and irrigation systems in the same regions growing similar crops. They conclude that a significant scope exists for increasing crop productivity in irrigated areas by manipulating key factors which include reliable irrigation supply and input use. As shown by Sharma et al. (Paper 10), small supplemental irrigation can double the productivity of crops in rain-fed areas. Study by Palanisami (Paper 13) explores ways of increasing the value of productivity through multiple cropping systems. This is a good strategy when there are limited opportunities for increasing productivity through mono-cropping systems.

Growth in Irrigated Area

Over the last few decades, irrigation expansion was the sole contributor to the growth in gross cropped area, and groundwater was the main driver behind this area expansion. In fact, the groundwater irrigation has contributed to all of the net irrigated area expansion in the 1980s and 1990s (Figure 8). Today it accounts for 60 % of the gross irrigated area of India. It shows that much of the expansion in recent decades, contrary to popular belief, has occurred outside major canal command area districts (Bhaduri et al.; Paper 11). In fact, the groundwater irrigation explosion in the last few decades was driven mainly by the population pressure and not necessarily by the water availability through return flows of surface water irrigation. Although the depth to groundwater in some areas is falling, overall expansion for groundwater shall continue in the future in many other regions.

The groundwater irrigated area has expanded at a rate of one million ha annually during the last decade and, in comparison, the surface irrigated area had virtually no growth over the same period. The NCIWRD scenarios assumed that much of the expansion in irrigated areas that will be required for meeting future food demand will come from surface irrigation. However, the trends in the 1990s show a stark deviation from this assumption. Such assumptions indeed

Figure 8. Net surface and groundwater irrigated area growth.



Source: GOI 2004; Amarasinghe et al. 2007.

have major implications on the financial cost and also on the total water demand. As regards the cost, expanding surface irrigation under the prevailing water scarcity conditions in many river basins will most probably require expensive IBWTs. As regards the water demand, surface irrigation may require significantly higher water withdrawals, as project efficiency of surface irrigation is much lower than groundwater irrigation.

Based on the present level of exploitation, availability, quality and the impact on environment, Sundararajan et al. (Paper 12) argue that there are only small pockets for developing further groundwater irrigation. However, as argued by Amarasinghe et al. (Paper 4), artificial groundwater recharge is an important policy prescription for sustaining the groundwater irrigation in many river basins. And, based on the present trends, Amarasinghe et al. 2007 shows that groundwater expansion will continue and the net groundwater irrigated area will reach about 50 mha, adding further 16 mha to the level in 2000.

Increasing Efficiency

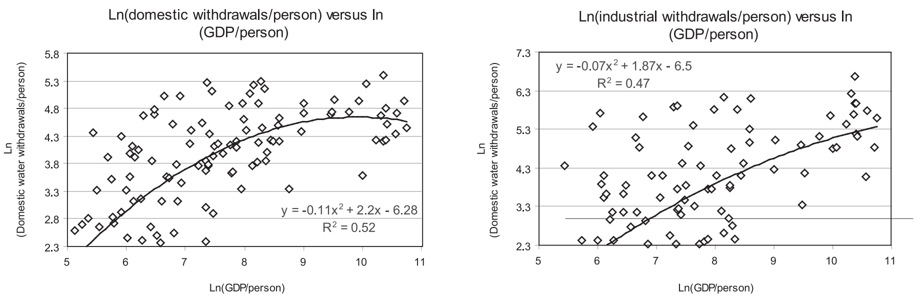
The project efficiencies of surface and groundwater irrigation systems are another major driver affecting irrigation demand projections. Many claimed that there is a significant scope for increasing project efficiency, especially in surface irrigation systems. However, the little information available suggests that the efficiencies of major systems are hovering around 30-40 % and no major increment of efficiency was also seen over the last few decades. Indeed, increasing irrigation efficiency in one location of river basins that are approaching closure may not yield the desired result of gains in overall efficiency, as it affects another user in the downstream of the closing basins. Thus, increasing surface irrigation efficiency to the level suggested by the NCIWRD projections, i.e., 60 % will have limited effect within the water stressed basins.

But it is clear that many water saving technologies, especially micro-irrigation systems, can significantly increase water use-efficiency. Narayanamoorthy (Paper 15) show that sprinkler and drip irrigation can have efficiencies in the range of 75-90 %. And, it also shows that more than 70 mha of land can potentially benefit from micro-irrigation. However, this potential can only be reached by overcoming many constraints. Spreading micro-irrigation systems in India is difficult due to the many marginal and small farmers, lack of independent source of water and pressurizing devices for these small farmers, poor extension services, lack of subsidies, unreliable electricity supplies etc. (Kumar et al. Paper 16).

Domestic and Industrial Water Needs

The economic growth, increasing income and lifestyle changes drive up the demand for water for the domestic and industrial purpose. Figure 9 shows that water demand in the domestic and industrial sectors increase rapidly with increasing income in the low to middle-income categories and the growth of water demand, especially in the domestic sector tends to stabilizes at the higher income level.

Figure 9. Domestic and industrial water demand in different countries.

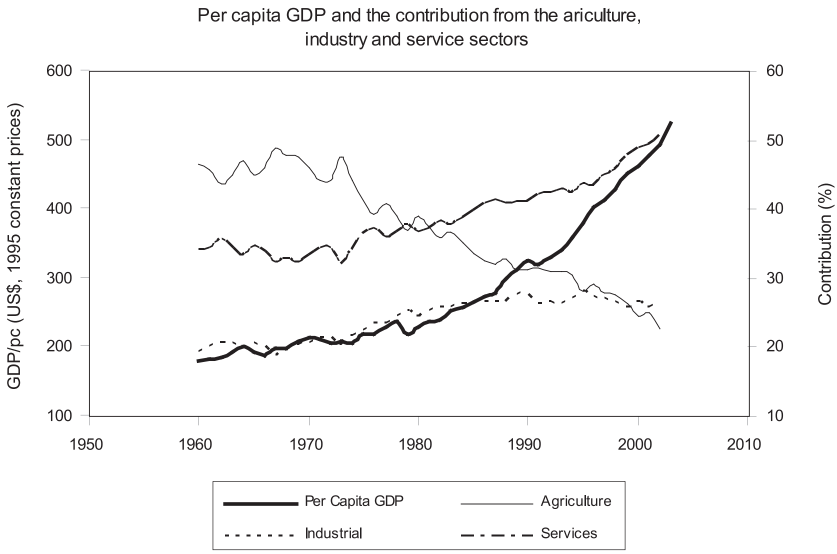


Source: WRI 2005

In India, the service and industrial sectors expanded rapidly in the 1990s and contributed to a GDP growth of more than 5.1 % annually between 1991 and 2002 (Figure 10). Over this period, per capita GDP has increased at 3.9 % annually, and it is growing 5.3 % annually in this decade. Such growth patterns in the economy will exert a significant pressure for water demand in the domestic and industrial sectors in the future. In fact, according to the current trends of economic growth and urbanization, most of the additional water demand between 2000 and 2050 could well come from the domestic and industrial sectors (Amarasinghe et al.; Paper 5). Whether that increasing water demand will be met through groundwater or surface water is an important secondary driver for assessing future water needs.

A national-level analysis (Sundararajan; Paper 19) reveals a significant spatial variation of the dependence of groundwater for municipal water supply. In peninsular India, primarily in hard rock regions, cities depend more on (average around 80 %) external sources of water. The size of a city is a strong indicator of how much surface water it can import from other areas. The alluvial aquifer cities are more dependent on local groundwater (average 75 %). However, as the city population grows its dependence on surface water will increase. And their willingness to pay for a reliable service shall increase too. Thus, growing cities and their population in India will be a major driver of increase in surface water for domestic and industrial sectors in the future. Such increase in demand could be a major justification for large intra-basin water transfers.

Figure 10. Contribution to GDP growth from different sectors in India.



Source: WRI 2006

Conclusion

There are clear trends that India will require substantial additional water supply to cater to increasing demand in the coming decades. It is estimated that India withdrew about 680 BCB for meeting the demand in the irrigation, domestic and industrial sectors in 2000. According to the recent growth patterns, the future demand is projected to increase by 22 % and 32 % by 2025 and 2050, respectively (Amarasinghe et al.; Paper 4). The population and economic growth, increasing world trade, the changes in lifestyles and food consumption patterns, technological advances in water saving technologies are the most influential primary drivers of India's water future in the short to medium term. The climate change will become an influencing factor in the long-term.

Over the last two decades, groundwater has been the major source for meeting increasing demand in all sectors. It is highly likely that this trend will continue. However, many river basins will have severe water stress conditions under business as usual water- supply and use patterns. With increasing reliance on groundwater, particularly for irrigation, many river basins will have severe groundwater overexploitation-related problems. Indeed, meeting India's short to medium term water demand itself will be a challenging task.

However, many options are available to meet this challenge (Amarasinghe et al.; Paper 5). Recharging groundwater to increase the groundwater stocks; harvesting rainwater for providing the life-saving supplemental irrigation; promoting water saving technologies for increasing water use efficiency; formal or informal water markets and providing reliable rural electricity supply for reducing uncontrolled groundwater pumping; increasing research and extension for enhancing agriculture water productivity; and carefully crafted virtual water trade between basins are important policy options for meeting the increasing demand. With increasing disposable income, people's affordability and willingness to pay for a reliable domestic and industrial water supply will increase. This, along with a reliable water supply for diversifying high value cropping patterns, may require large surface water transfers. The interbasin water transfers could increase the recharge groundwater in much overexploited area.

While artificial groundwater recharge, rainwater harvesting, and interbasin water transfers are a solution for meeting the water demand in the near-term, they are also solutions for increasing the potential utilizable water supply in many water scarce river basins. They will indeed have major benefits when full influence of the climate change starts to impact the utilizable supply in many water scarce river basins.

References

Amarasinghe, U. A.; Shah, T.; Turral, H.; Anand, B. 2007. *India's water futures to 2025-2050: Business as usual scenario and deviations.* Research Report 123. Colombo, Sri Lanka: International Water Management Institute.

Bandyopadhyaya, J.; Perveen, S. 2003. The Interlinking of Indian Rivers: Some Questions on the Scientific, Economic and Environmental Dimensions of the Proposal. Paper presented at the Seminar on Interlinking Indian Rivers: Bane or Boon? at IISWBM, Kolkata, June 17, 2003. SOAS Water Issues Study Group, Occasional Paper No. 60.

CGWB 2008. Master Plan for Artificial Recharge to Groundwater in India. http://cgwb.gov.in/documents/MASTER/20PLAN/20Final-2002.pdf.

CPWF 2005. Strategic Analysis of India's River Linking Project. The Project Proposal. www.cpwf.org

CWC 2004. Water and related statistics. New Delhi: Water Planning and Projects Wing, Central Water Commission.

Falkenmark, M.; Lundquvist, J.; Widstrand, C. 1989. Macro-scale water scarcity requires micro-scale approaches: Aspect of vulnerability in semi-arid development. *Natural Resources Forum* 13 (4): 258-267.

Garg, N. K.; Hassan, Q. 2007. Alarming scarcity of water in India. *Current Science,* Vol. 93, No. 7. 10 October 2007.

GOI 1999. Integrated water resources development. A plan for action. Report of the Commission for Integrated Water Resource Development Volume I. New Delhi, India: Ministry of Water Resources.

GOI 2005. Agricultural Statistics at a Glance 2004. New Delhi, India: Ministry of Agriculture, Government of India.

Gosain, A. K.; Rao, S.; Basuray, D. 2006. Climate change impacts assessment on hydrology of Indian river basins. *Current Science,* Vol. 90, No. 3. 10 February 2006.

IWMI 2005. The India's Water Futures Analyses. Scenarios and Issues. Unpublished Proceedings of the Inception Workshop on the Project 'Strategic Analyses of India's Water Futures'

IWMI 2000. World water supply and demand 1995 to 2025 (draft). www.cgiar.org/iwmi/pubs/WWVison/WWSDOpen.htm

Kumar, M. D.; Samad, M.; Amarasinghe, U. A.; Singh, O. P. 2006. Rainwater Harvesting in Water-scarce Regions of India: Potential and Pitfalls. Draft prepared for the IWMI-CPWF project on 'Strategic Analysis of National River Linking Project of India'.

Mall, R. K.; Gupta, A.; Singh, R.; Singh, R. S.; Rathore, L. S. 2006. Water resources and climate change: An Indian perspective. *Current Science,* Vol. 90, No. 12. 25 June 2006.

NWDA 2006. The Inter Basin Water Transfers: The Need. Accessible via http//nwda.gov.in/

Shah, T. 2000. Mobilizing social energy against environmental challenge: understanding the groundwater recharge movement in western India. *Natural Resources Forum* 24 (3): 197-209.

Shah, T 2008. An Assessment of India's Groundwater Recharge Master plan. Draft prepared for the IWMI-CPWF research project 'Strategic Analysis of India's National River Linking Project'**.**

Shah, T.; Amarasinghe, U. A.; McCornick, P. G. 2006. India's River Linking Project: The State of the Debate. Draft prepared for the IWMI-CPWF project on 'Strategic Analysis of National River Linking Project of India'.

Smakhtin, V.; Anputhas, M. 2006. *An assessment of environmental flow requirements of Indian river basins.* Research Report 107. Colombo, Sri Lanka: International Water Management Institute.

Smakhtin, V.; Arunachalam, M Behera,.; S.; Chatterjee, A.; Das, S.; Gautam, P.; Joshi, G. D.; Sivaramakrishnan, K. G.; Unni, K. S. 2007. *Developing procedures for assessment of ecological status of Indian river basins in the context of environmental water requirements.* Research Report 114, Colombo, Sri Lanka: International Water Management Institute.

World Bank 2005. India's Water Economy: Bracing for a Turbulent Future. Draft Report. http://go.worldbank.org/QPUTPV5530

WRI (World Resource Institute) 2007. Earth Trends. Environment Information. http://earthtrends.wri.org/searchable_db/index.php?theme=5